

§17. ICRF Heating Experiment in Heliotron J

Mutoh, T., Kumazawa, R., Seki, T., Saito, K., Kasahara, H., Okada, H., Minami, T., Sano, F., Hanatani, K., Mizuuchi, T., Kobayashi, S., Nagasaki, K. (IAE, Kyoto Univ.), Nakamura, Y. (Grad. School, Energy Sci., Kyoto Univ.)

Main purpose of this study is to understand the heating mechanism of ICRF heating in the Heliotron J magnetic field and improvement of the heating efficiency. For the minority heating scheme, the fast ion generation and its confinement are key issues because the RF energy is absorbed mainly by the minority ions. We investigated the heating position dependence of the fast ion confinement and the heating efficiency in FY 2009.

Fast ion velocity distribution has been studied using fast protons generated by ICRF minority heating in Heliotron J, a low-shear helical-axis heliotron ($R_0 = 1.2$ m, $a = 0.1$ - 0.2 m, $B_0 \leq 1.5$ T). The configuration used in this study is STD configuration of Heliotron J. The majority species of plasma is deuteron and the minority ion is proton. The minority ratio is about 10%. Two loop antennas are installed at the corner section of Heliotron-J plasma, where the mod-B structure is tokamak-like. By changing ICRF frequency, the cyclotron resonance position is changed from the on-axis ($f=19$ MHz) to the inner side of the torus ($f=23.2$ MHz, off-axis heating). The fast ions are measured by a charge-exchange neutral particle energy analyzer (CX-NPA) installed at the toroidal angle opposite to the ICRF antenna position.

The line-averaged density of ECH target plasmas and ICRF injection power were $0.4 \times 10^{19} \text{ m}^{-3}$ and about 0.28 MW, respectively. The energy spectra obtained in two heating position are shown in Fig 1 (a) and (b). The pitch angle dependence is obtained by changing the toroidal angle of the CX-NPA. The effective temperature is estimated from the energy spectrum in the energy range from 0.8 keV to 7 keV as shown in Fig. 1 (c). The effective temperature in the on-axis case is higher than that in the inner-side heating case. In both cases, pitch angle dependence is observed. They have peaks around 120 deg in pitch angle.

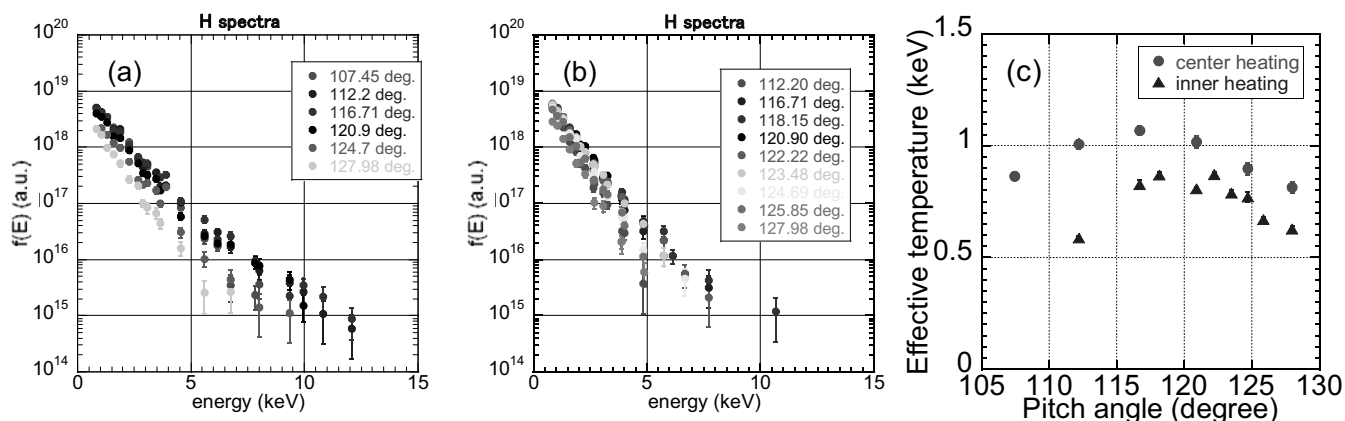


Fig.1 Pitch angle dependence of minority-ion energy spectra: (1) on-axis heating, $f = 19$ MHz, (b) off-axis (inner-side) heating, $f=23.2$ MHz, (c) Effective temperature of minority ion.

Bulk deuteron energy spectrum was also observed using measurement of the CX-NPA. From the spectrum, the bulk ion temperature can be estimated. The pitch angle dependence was not observed in the estimated temperature. In this experiment, the observed chord of the CX-NPA always crosses the magnetic axis. In addition to the low density condition, it seems that the estimated temperature corresponds to the central temperature. The power dependence of the bulk temperature is shown in Fig.2. In the contrary to the fast minority ions, the bulk temperature in the off-axis heating is higher than that in the on-axis case.

In the minority heating scheme, the injected wave energy is firstly absorbed by minority ions and then, it delivers energy to the bulk ions and electrons. The experimental result is not consistent with the usual picture of minority heating. Fast ions are, however, sometimes

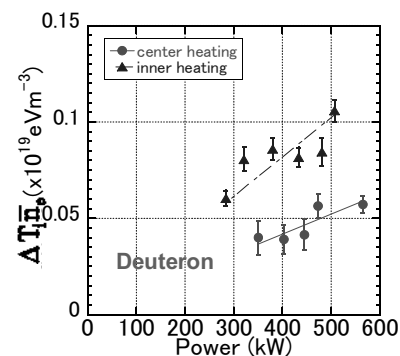


Fig. 2 Power dependence of the ion heating efficiency for the two heating positions.

localized in a plasma. The measurement area in the experiment is limited. The averaged fast ion spectrum for the whole plasma volume must be estimated for the next step. It is very difficult to be done experimentally; then, the development of the numerical model by using TASK/WM and Monte Carlo method is in progress.

- 1) H. Okada, et al., "Heating Position Dependence of Energy Spectra of Fast Ions Generated by ICRF Heating in Heliotron J", Proc. 17th ISHW, Oct. 12-16, Princeton (2009) P03-18.